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Ubiquitous crime prevention system (UCPS) for a safer city

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Abstract

Since crime has damaged citizens' lives and properties, establishing a safe urban environment has been a crucial social issue. New approaches using big data and ICT prove to reduce crime rates. This study therefore reports the results of big data analyses, which includes not only real crime data, but also urban attributes such as land use, and pedestrian flows, etc. A 'Ubiquitous Crime (U-Crime) prevention system (UCPS)' operating on the web is proposed. The results can be used as a guideline for system development and a decision support system for establishing security policies.

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Keywords: Safe city, U-City, big data, crime analysis, crime prevention.

1. Introduction

A wide range of urban issues such as housing, traffic, environmental problems have been emerging as a result of rapid urbanization and population increase. In addition, small and big crimes in urban areas have damaged our lives and properties. Therefore, the creation of a safer urban environment has become a crucial social issue. In Korea, even though there was a slight decline in crimes recently, crime rates have increased by 3.4% on a yearly average over the last 30 years. Due to the increase of heinous crimes such as murder, robbery, and rape, people's anxiety has been intensified.

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In this regard, the Korean government plans and develops the U-Crime Prevention Service of Ubiquitous City (U-City) to create a safe city against crimes. U-City is a Korean smart city. It features 228 diverse U-Services that include U-Traffic, U-Parking, U-Crime Prevention, etc. The installation of CCTV has been expanded and control centers were built in many cities to manage them. However, satisfactory achievements have not been made yet. Because the system involves excessive costs, it was not equipped with a satisfactory level of funding and sufficient functions. In addition, the crime analysis and academic approach is restricted because police does not release the real crime data yet in Korea for reasons of privacy and private property rights.

Therefore, Korea needs to reconsider government policy and research direction. The main idea is to make a cost-effective crime prevention system. It may not be possible to cope with crimes, only with the police force or crime prevention facilities, such as CCTV, IT sensor, etc. Instead a system that utilizes Internet or smart phones and provides local crime information to the citizen can be a convincing alternative.

The system helps people to be aware the dangerous places and always be prepared against crime whenever they approach the dangerous area. In addition, academic research which analyzes the diverse crime information and predicts the occurrence of crime is needed. Especially, an analysis of real crimes and crime prevention strategies should be provided by analyzing the behaviors of people using a huge volume of big data, produced by smart phones, Internet, and SNS.

This study presents a 'U-Crime Prevention System (UCPS)', which operates on the Internet and an App in the study area. However, this study is at an early stage of development, so that it explores mainly the system components and attempts to approach the system from the perspectives of big data, which lately have received people's attention. The system is preferable composed of factors that affect crime occurrence. Therefore, this study analyzes public big data such as pedestrian flows, credit card usage that smart phones and diverse IT devices produce, but also land use and building usage that features the physical urban environment. The collected big data will be analyzed by spatial statistical analyses to identify the factors affecting the occurrence of crime and then provide the crime information to the general audience through the Internet or the App with visualized images like a crime map.

UCPS has the advantage of preventing crime in advance by identifying the crime information about a user's surrounding area. It contributes to creating a safe city through organizing police patrol and managing the suspicious and dangerous areas.

2. Crime prevention theories and big data

2.1. Crime prevention

Various crime prevention theories have recently emerged, ranging from traditional 'defensible space theory', 'routine activities theory', 'situational crime prevention theory' to the 'Crime Prevention Through Environmental Design (CPTED) (Table 1).

Table 1. Crime prevention theories.

Theory	Short description
Defensible space	Territoriality, natural surveillance, image, milieu, safe adjoining areas are essential factors Crime can be reduced through improving physical environment, which affects crime occurrence
Routine activities	A sub-field of crime that focus on situation of crime occurrence Life style should be changed to reduce crime opportunities
Situational crime prevention	Similar to the 'Crime Prevention Through Environmental Design (CPTED) Reduce potential crime opportunities through creating environment, which blocks the access of criminals
CPTED	Prevent crime occurrence by improving physical urban environment factors

In the past, crime theories were interested in the measures after crime occurrence such as penalty, punishment, correction, and treatment, but since the 20th century, the concern has moved to crime prevention. Crime prevention has been unfolded in various ways such as defensible space and environmental design. These theories aim to create a safer city against crime through improving urban space.

This study will emphasize the spatial aspects of the city for crime prevention. Although there have been many research examples illustrating the spatial approach, only some have explored geographic patterns of crime occurrence[1,2]. These studies explored the spatial distribution of crime from the ecological perspectives of the Chicago School. However, their social ecology has received abundant criticism and has lost its support since the 1940s.

Since then, new experiments, which tried to reduce crime through the improvement of the physical environment of the city, have emerged. As a new academic discipline of crime study, 'environmental criminology' has been advanced. It analyzed various factors such as criminals, victims, criminal purpose, and social norms as well as criminal behavior. Environmental criminology began in the late 1980s and it has developed rapidly with the advent of the theory of crime prevention in the 1990s[3,4,5].

2.2. Big data

The phenomenon of digital data deluge was pervasive over the last 10 years. During this period, the Internet has become our daily routine. Huge data has been produced in accordance with the exponential increase in the volume of digital information, leading to the term 'big data'. Big data refers to the set of huge data which cannot be controlled with existing management and analysis systems[6]. In the early period of big data, the exact definition of the idea of big data received a lot of discussions. However, recently the concern has been transferred to data sharing and their utilization. Big data is used for predicting social phenomenon. As a representative case, we can take the example of Decide.com, which predicts the price of electronic products and Obama.com which predicts the election results of the presidential elections.

This study expects that big data can be used for the analysis and prediction of crime occurrence. The scenes of crime prediction shown in the 'Pre-Crime' of the film titled 'Minority Report' are likely to be realized soon. However, big data need to be well-organized and require a systematic approach. In this regard, this study attempts to develop a 'U-Crime Prevention System (UCPS)', which is operated on the Internet and smart phones by analyzing and utilizing the big data related to crime.

3. Crime information systems

Crime information systems which are running in the world were examined by classifying them into two types, web and mobile. The cases were selected by surfing the Internet with key words such as 'crime prevention', 'safety', 'relief', 'crime', 'criminal', 'safety', 'offender'. In the case of mobile apps, surfing iPhone app was available in the APP store on iTunes and surfing Android app was available in the Android market, KT Olleh market, and SKT T store. As the app market changes quickly, the investigation was conducted twice in August, 2013 and February, 2014.

Web-based crime information systems in Korea are largely divided into two types, those used by police and private. The police operate 'Crime Information Management System (CIMS)' and 'Integrated Portal System (IPS)'. IPS is developed for the integrated utilization of the data scattered in each department to strengthen the initial response to urgent and heinous crimes such as kidnapping and murder by sharing crime data and techniques required for police investigation. In case of the private sector, there are portals, titled 'Cyber 112', 'Safety Dream', 'Youth School Violence', and 'Fall in Love'. 'Crime Hunter' is the most activated site.

In British, police website (http://www.police.uk/) is comparatively active, and provides crime information up to 2 ~ 16 months. This system can make people grasp and prevent crimes by providing crime places, crime types, and other valuable regional crime information. In San Francisco, 'Data SF (http://sanfrancisco.crimespotting.org/)' provides a variety of information about crime rates, maps, street names, highway information and police offices with the mesh-up type service. Therefore, people can become aware of the current crime locations in San Francisco and search for the crime-ranked districts and crime information about their surrounding area.

'CrimeReports (https://www.crimereports.com/)' provides official crime information in 15 states in the USA in cooperation with the police. In addition, this site analyzes crimes that occurred during the last month and presents the results to the public. Meanwhile, it developed an app, which connects users with email alerts or cell phone services. The website of Brazil, 'wikicrimes (http://www.wikicrimes.org/)' presents a crime hot spot map and allows the users to inquiry regional crime data such as crime statistics, dates, time, and crime type. Similar systems can be found in many other cities and countries across the world.

Table 2. The main contents of the crime information systems

Tools and functions		Contents and feature	Technique
Crime map	Visualization of crime information	Crime spot, date, techniques, and damage	Location recognition, search, network information, visualization
	Risk assessment	Grading the safety Adopted in UK and US where are positive in opening the crime data	Geographical information, location recognition, AR
Information offering	Text, picture, video	Information on the wanted criminal, missing person or child Knowledge for preventing crime & coping measures at emergency Crime statistics	Location recognition, search, network, information visualization
	Map	Location of crime prevention facilities Crime statistics	Geographic information, location recognition, AR
Guarding	Alarming, Report	Informing the moving track of the user in real time by phone or SNS Risk alarming through the smart phone Automatic signal sending to acquaintance though SNS	Location recognition, SNS, SMS
	Surveillance, remote control	Remote control or surveillance by connecting webcam or surveillance camera in the smart phone Alarming or automatic report	Remote control, NFC
User participation	Text, picture, video	Sharing of crime information with the parents, teachers, and residents of school children Crime information DB, connection with the local police, user report Location based SNS, establishment of crime prevention networks	Location recognition, SNS, AR
	Map	Witness location and information about crime occurrence Information-sharing by marking the map in the location where fear is felt.	Geographic information, AR

Table 3. The features of the crime information systems

Web/mobile		System name	Operating entity	Crime prevention map		Tools		Guarding		User participation	
				Info. visualization	Risk assessment	Text, picture, video	Map	Alarming, report	Surveillance /remote control	Text, picture, video	Map
Web	International	The UK CID website	Gov.	○	○	○	○			○	○
		San Francisco Data SF	Private	○	○		○			○	
		the USA CrimeReports	Gov.	○	○	○	○			○	
		Brasil wikicrimes	Private	○	○	○	○			○	
	Korea	Police info. management system	Gov.							○	
		Cyber 112 report & petition portal	Gov.							○	
		Fall in love	Gov.							○	
		Safe Dream Youth school violence	Gov.							○	
		Crime hunter-Daum café	Private			○				○	
Mobile	Korea	Safe return	Gov.		○		○	○			○
		Portable CCTV, Secu-EYE	private					○	○		
		Seoul safety keeper	Gov.					○			
		Safe overseas trip	Gov.			○	○	○			
		Safe return QR-cop	Gov.				○	○			
		Smart safe return (1)	Gov.					○			
		Smart safe return (2)	Gov.				○	○	○		
		Smart safe return	Gov.			○	○	○			
		Safe taxi call	Private			○		○			
		Hello taxi	Private				○	○			
		Nabi call	Private				○	○			
		Safe dream	Gov.				○	○		○	
		Shaking & crime prevention	Gov.					○	○		
		It's a wolf	Private				○	○			

Meanwhile, many crime prevention apps using smart phones have been developed and more demand for apps is expected. However, a considerable number of apps only hold simple functions such as alarming, notification, monitoring and remote control. Therefore, apps have limitations, even though they have an immediate crime countermeasure when users encounter a crime. We analyzed various crime information systems implemented in several countries. The contents and functions of the system are classified into the crime map, information-offering, guarding, and user participation (Table 2).

Table 3 describes the crime information systems, based on these four categories. In case of Korea, the map-based location information is equipped and the user participation function is embedded. However, the Korean case does not provide specific crime places or detailed information due to concerns about land price decline or the protection of privacy. Nonetheless, safety maps have been produced and made available to the public, even though they do not include the actual crime data. For example, safety information systems such as 'Living Empathy Map' and 'Tubeoki Safe Path' are demonstrated by the Ministry of Security and Public Administration. These systems provide the location information of crime prevention facilities such as CCTV, the police station, and 'children's safety house'.

4. Case study

4.1. Study area

This study selected J City in Korea as the case study area. J city with a population of 337,314 in 2012 is located in the central southern part of the Korean peninsula and is a historic city built around the castle in the downtown. Currently, it is a slow-growing city based on agriculture due to delayed industrialization. According to the crime report issued by the local police in 2012, the total crime reached 3,560, committed in J City as shown in Fig.1, 2. The darker the area, the higher the crime rate. The crime hot spots appear around the civic center. Crime rate is very low in the industrial area located in the southeastern part of the city.

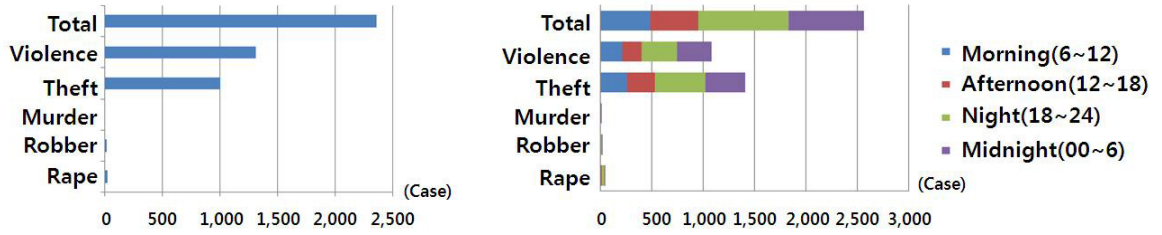

Fig. 1. Crime occurrence by types and time of the day in J City.

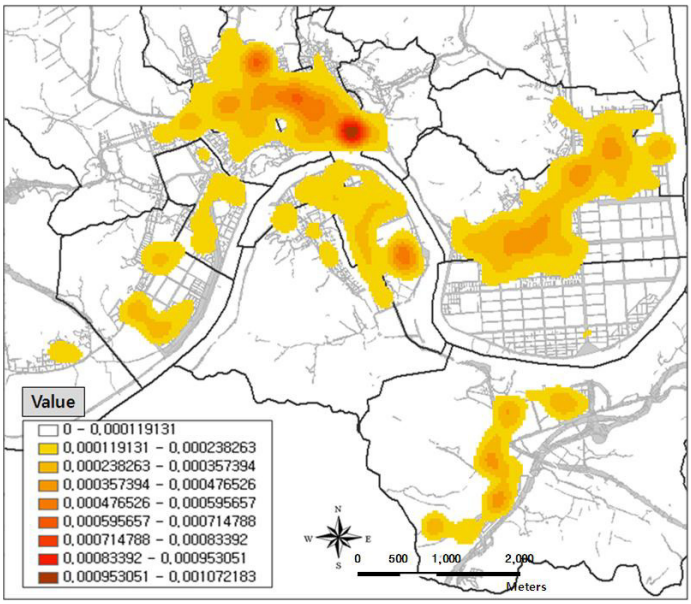

Fig. 2. Crime density in J City.

4.2. Exploration of big data related to the crime occurrence

Since the police in J City records crime occurrence in text format, it is difficult to search for the exact crime places on a map and execute statistical analysis. In addition, since Korean cities have been progressed into a smart city by taking advantage of state of the art IT and citizen's usage of individual smart devices increases, producing a huge amount of communication data, the crime data required to be collected and managed systematically. In particular, big data can be effectively used in the field of crime prevention.

The data which have been used in existing studies and systems are shown in Table 4. The data can be largely divided into public and private data. The public data consists of the basic and physical characteristics of the city, such as population, public transportation information, land use, building usage, and urban infrastructure and facilities, while criminal information includes crime occurrence data and CCTV.

As private data, pedestrian flows, shops and sales amount of each shop can be utilized. However, in order to develop an effective crime prevention system architecture, this study tries to analyze the influential factors of crime occurrence more specifically by utilizing the collected variables.

Table 4. Possible data set for UCPS.

Data source	Factors	Detailed variables	Data forms
Public	Population	Population, demographics, gender, percentage of foreigners, populated areas, etc.	Statistics
	Land use zoning	Land use, residential, commercial areas, etc.	WMS, WFS, XML
	Development projects	Current conditions of urban development, redevelopment, reconstruction of housing	WMS, WFS, XML
	Local civil complaints	Complaints and their locations	Statistics
	Building	Building shape, building usage	GIS shape file
	Urban facilities	Roads, parks, parking lots, schools, etc.	WMS, WFS, XML
	Crime occurrence	Date, location, type of crime	Text
	CCTV	CCTV location, specification	Point, text
	Police station, community security center	Location	Point
	Sex offender	The location of sex offender's residence	Statistics
	Public transportation	Traffic information	OPEN API
Private	Pedestrian flow	Pedestrian flow by time, genders, ages	Point
	Business information	Location of business place	Point
	Sales information	Sales amount by time	Text
	Network data	Geographic Information	Poly line

4.3. Crime occurrence and CCTV

Apprehending criminals through CCTV has been frequently reported and the installation of CCTV has increased rapidly. There were several negative studies in regard to the effect of CCTV[7,8], but the installation of CCTV is expected to increase for a while in accordance with the citizens' demand and social atmosphere. However, specific guidelines on the installation of CCTV have not been settled yet.

In the case of Korea, CCTV has been installed following 'The Guidelines of Image Information Processing Equipment'. However, the installation standards are not clearly formulated. Local governments usually install CCTV around residential areas and school zones, but CCTVs are not efficient because crimes are not common in these areas. To confirm whether CCTVs are properly installed in the crime hot spots, spatial analysis using GIS was conducted. In regard to the crime occurrence data, the crime management book of 2008 and 2011 recorded by local police, was used. Based on the addresses of crime occurrence data, the crime place was set as points on the map. Adding crime attributes to the point, a crime geographic information system was made. In J City, 876 CCTVs were installed in 264 locations. Among them, 115 CCTV cameras for crime prevention were identified in 24 locations (Table 5).

Table 5. CCTV in J City.

	Disaster and fire*		Littering violation*		Facility management*		Crime prevention*							
Installation purpose	River monitoring	Facility management	Crime-prevention	Prevention of littering	Crime prevention	Facility management	School zone	Decoding vehicle no.	Traffic control	Littering & park management	Park management	Crime prevention **	Parking violation **	Totals
No. of installation	6	1	32	8	120	214	257	26	32	2	43	115	20	876
Installation location	6	1	32	1	4	27	113	4	11	1	14	24	8	246

* Multi-purpose CCTV ** Single purpose CCTV

Fig. 3 shows the overlay of actual crime occurrence and CCTV installation locations. CCTVs were intensively installed in residential areas and school zones rather than in high crime areas. Next, in order to find how effective the CCTV is installed in the study area, we again conducted an overlay analysis with the real crime and CCTV surveillance boundary. Though the spatial coverage of CCTV surveillance is different, depending on their mechanical performance, this study adopted 50 m for object recognition.

As a result, the circles in Fig. 4 are the spatial coverage of artificial surveillance by CCTV, and the spots are the points of crime occurrence. This shows how CCTVs are installed differently from the reality of crime occurrence and how inefficiently they have been located. Thus, more specific and detailed guidelines of CCTV installation are required.

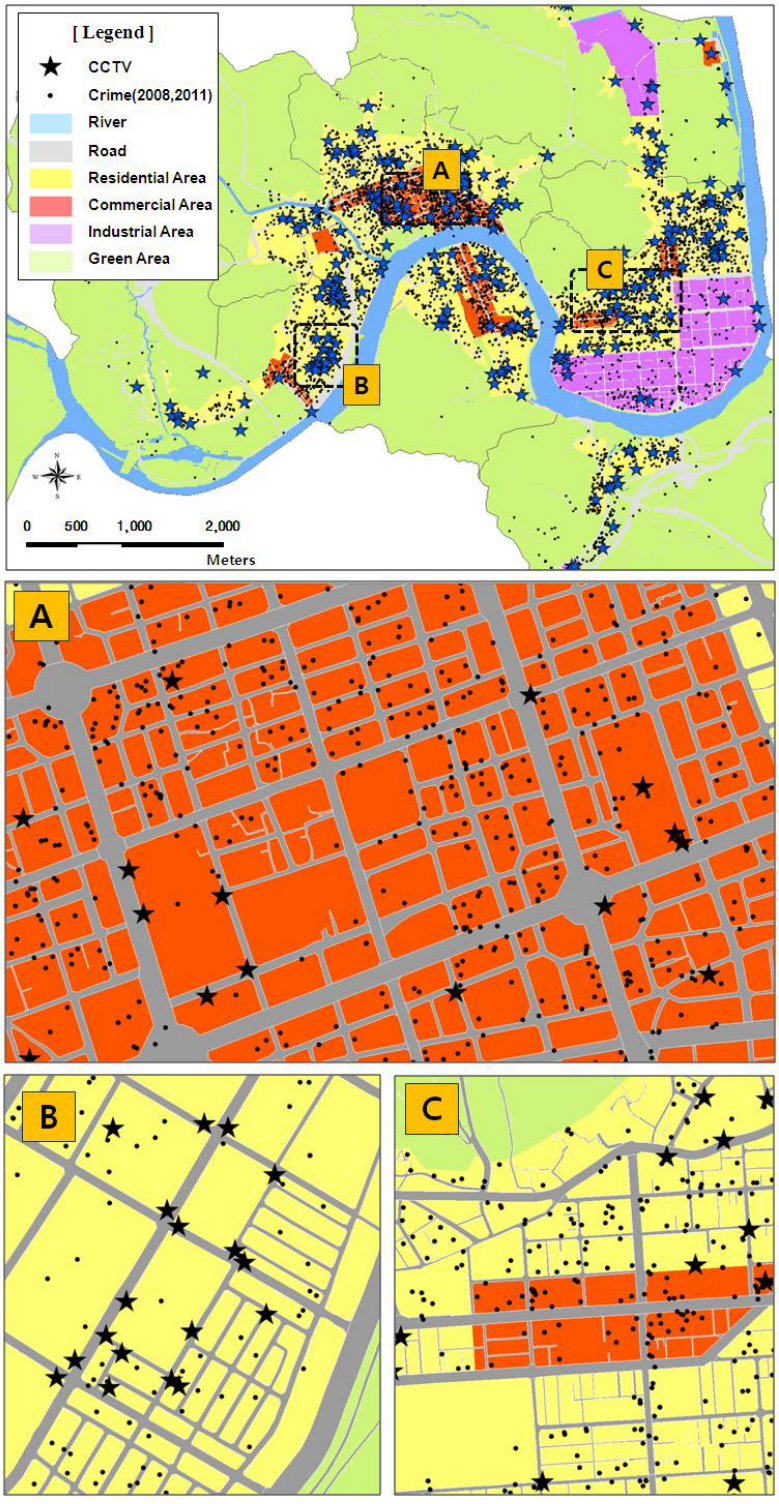

Fig. 3. Spatial overlay of crime location and CCTV.

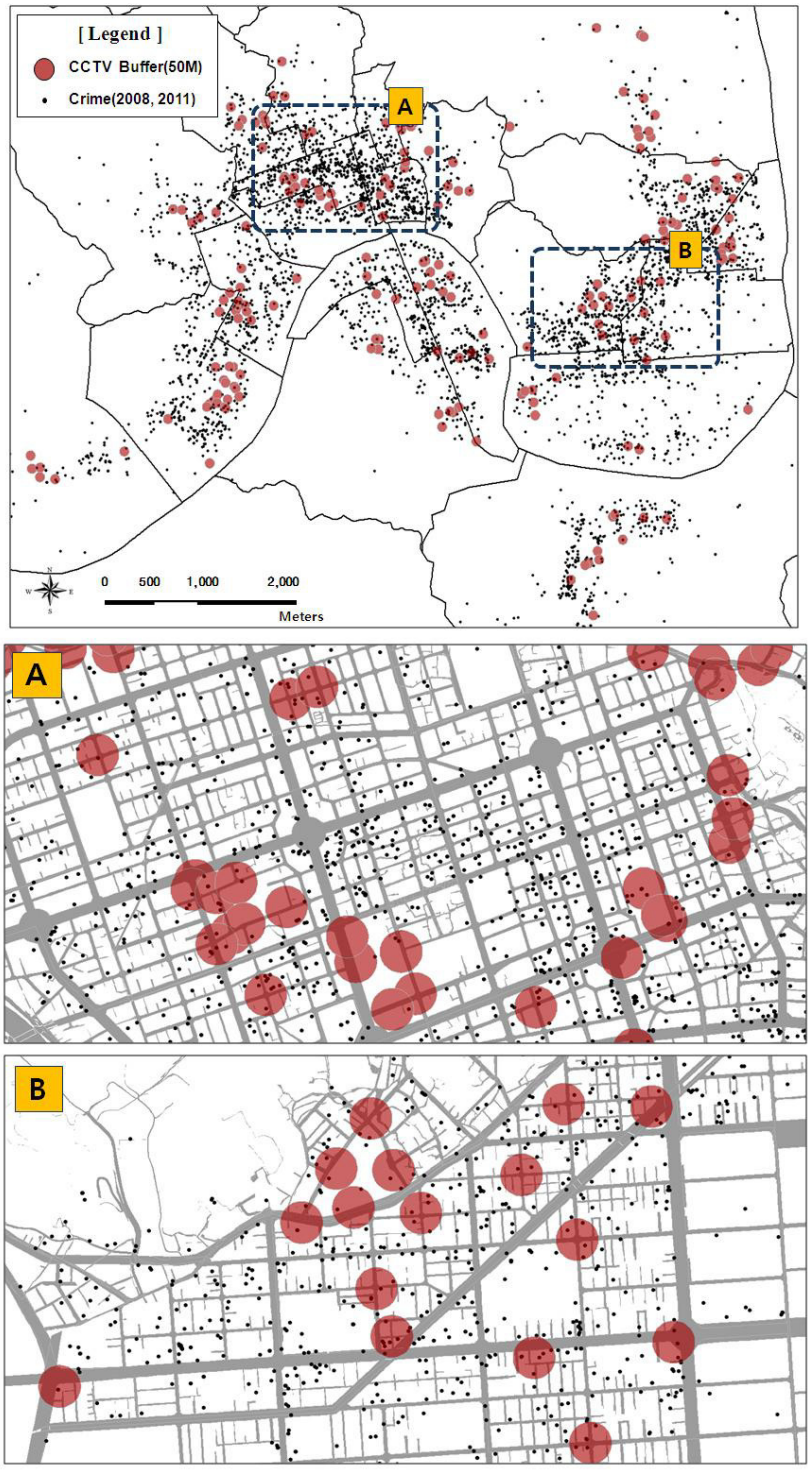

Fig. 4. Spatial overlay of crime location and spatial coverage of CCTV surveillance.

4.4. Crime occurrence and pedestrian flows

Pedestrian flows are people moving within the city. This study examines whether pedestrian flows are significantly correlated with crime occurrence. Pedestrian flows were obtained by GPS equipped smart phones or various IT devices. The data was provided by the Korea Telecomnunications Company and SK Telecom, and included age, gender and time zone. SK Telecom established the big data within a range of 50m x 50m.

This study analyzed the relationships between crime occurrence and pedestrian flows by selecting areas of high crime occurrence. The areas are located in the typical central business district in J city, where shops, restaurants, pubs, and offices are concentrated. Pedestrian flows are the highest in the afternoon, followed by night, morning, and late night. In terms of gender, men outnumbered women (Tables 6 and 7).

Table 6. Crime occurrence in J City (person (%))

Time-zone	Morning	Afternoon	Night	Late night
Pedestrian flow	459 (26)	790 (45)	468 (27)	46 (3)

Table 7. Average pedestrian population according to genders and ages in case districts (person (%))

Age group	10s	20s	30s	40s	50s	over 60s	Average
Men	296 (4)	1,511 (23)	1,303 (20)	1,554 (24)	1,374 (21)	555 (8)	1,099
Women	291 (7)	1,043 (25)	929 (22)	903 (21)	734 (17)	345 (8)	708

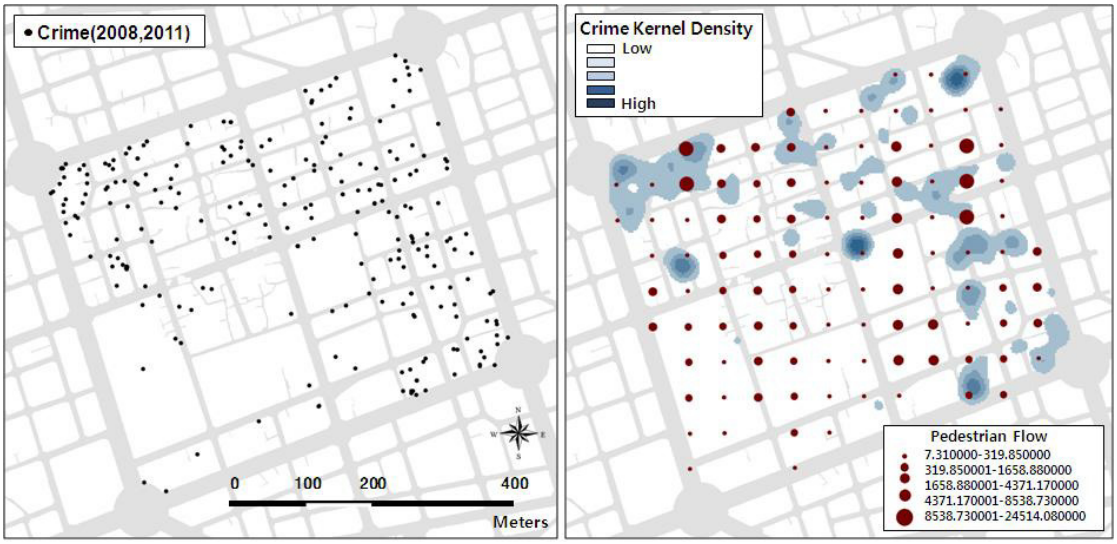

Fig. 5. Spatial overlay of crime location and pedestrian flow.

More crimes occurred close to commercial and public facilities. Examining the overlay of the actual crime occurrence and pedestrian flows, shown in Fig. 5, it is difficult to find strong relations. However, in this analysis, the objects of the study are confined to particular parts of the built-up area. Therefore, to identify trends in the entire city, the analysis needs to expand the boundary or differentiate between crime type, age, time of the day etc.

4.5. Urban environment factors affecting crime occurrence

Though there is a variety of information which will be provided through the UCPS, it is preferable to make the UCPS with the factors that are highly related to crime occurrence. Thus, this study attempts to investigate urban environmental factors. Variables input to the regression model are shown in Table 8. These variables were chosen from variables which were identified as influential factors of crime occurrence from the literature review. Selected variables include street with, number of floors, different type of facilities and neighborhoods, and building coverage.

Table 8. Variables for the spatial regression model.

Variables		Description	Unit	Sources
Dependent variable	Crime	Total Crime in 2008 and 2011	Case	Crime book
Independent variable	Physical environmental elements	Street width	m	Map
		Building floors	floor	Building management book
		Floor area ratio	%	
		Building coverage		
	Usage of the first floor	Type I neighborhood living facility*	ea.	Field survey
		Type II neighborhood living facility**		
		Accommodations		
		Recreational facilities		
		Commercial facilities		
		Office facilities		
		Houses		

* Type I neighborhood living facility means neighborhood center office, police station, fire station, supermarket, retail shop, barber shop, hair salon, public bath, etc.

**Type II neighborhood living facility means restaurant, private education institute, realtor office, cinema, etc.

Data was analyzed first by ordinary least squares (OLS). Then, spatial lagged models (SLM) and spatial error models (SEM) were applied, which can be viewed as spatial regression models. The OLS method minimizes the sum of squared vertical distances between the observed responses in the dataset and the responses predicted by the linear model. The SLM method uses maximum likelihood to estimate a spatial regression model that includes a spatially lagged dependent variable. Similarly, the SEM method estimates a spatial regression model that includes a spatial autoregressive error term using maximum likelihood. The results are shown in Table 9. In the case of OLS, Jarque-Bera statistics appeared to be 54.93 (p=0.000), indicating strong non-normality. The Breusch-Pagan value was 11.50 (p = 0.04), suggesting that heteroscedasticity exists. In addition, based on LM-Lag and LM-Error, the null hypothesis spatial independence of errors was rejected at the 1% significance level (Table 9). Therefore, SLM and SEM should preferably be applied rather than OLS.

R^2 in Table 9 which represents the explanatory power of the spatial regression model appeared to be highest for SEM (0.57), followed by SLM (0.52), and OLS (0.38). However, SEM showed the smallest log likelihood (-63.01), Akaike information criterion (AIC) (140.02), and Schwarz criterion (SC) (148.83) values.AIC offers a relative estimate of the information lost and SC value increases also when unexplained variation in the dependent variable. Hence the preferred model is the one with the minimum AIC and SC values.

Therefore, SEM was considered to be the most suitable model. Thus, using this model, street width, number of building floors, floor area ratio, type II neighborhood living facilities, recreational facilities, commercial facilities, and housing showed positive relations with crime occurrence. 'Type I neighborhood living facility (neighborhood

center office, police station, super market, and so on)' appeared to have a negative relation with crime occurrence. In terms of the blocks where the crime rate is low, we could identify through the field survey that a large number of Type I neighborhood living facilities were located here and quite many CCTVs were installed.

The effect of street width is significant and positive. The positive effect probably expresses the balance between the positive impact of a wide street to easily leaving the crime scene and the negative impact of a wide street to have less protection for being discovered. Crime rates were also found to be negatively related to the number of building floors.

Table 9. The results of OLS, SLM and SEM analysis.

Model		OLS	SLM	SEM
Constant		-6.50	-11.26***	-8.74*
Physical Environmental elements	Street width	0.02**	0.02***	0.02***
	Building floors	-0.01	-0.01**	-0.01**
	Floor Area Ratio	4.48*	3.64**	3.73
	Building coverage	21.97	-24.87	-62.72
Uses of the first floor	Type I neighborhood living facility	13.33***	0.33**	-3.14***
	Type II neighborhood living facility	0.02***	59.86*	95.61***
	Accommodations	2.09	1.77**	-2.28
	Recreational facilities	0.95*	0.97*	0.96*
	Commercial facilities	7.21**	6.32**	7.03**
	Office facilities	2.36**	2.47***	2.42
	Houses	59.71	-13.99***	76.87**
Explanatory power	R^2	0.38	0.52	0.57
Suitability of the model	Log likelihood	-66.64	-64.19	-63.01
	AIC	147.28	144.385	140.02
	SC	156.09	154.45	148.83
Normality	Jarque-Bera	54.93***		
Homoscedasticity	Breusch-Pagan	11.50**	11.03**	10.66**
Dependency	Likelihood ratio		4.89**	7.26***
LM-Lag		7.94***	7.46***	0.85
LM-Error		0.89***		

* < 0.1 ** < 0.05 *** < 0.01

5. Conclusion

U-Crime Prevention System (UCPS) that this study intends to develop need to be designed with an effective system architecture and easy-to-understand crime prevention information. Thus, in the previous sections, we attempted to find the elements that are highly related to crime occurrence by examining the case systems and big data. In particular, we investigated public data such as land use, building usage, urban infrastructure, and the information of CCTV location. In addition, we extracted private data provided by telecom companies, which is

generated in daily routines using smart phones and various IT devices. We extracted influential factors on crime occurrence through spatial regression analysis. Finally, we summarized the important factors for the designing UCPS architecture.

By comparing the spatial density pattern of pedestrian flows and the location of CCTV with the location of real crime occurrence, we revealed that CCTV does not match the place of crime occurrence. Thus, CCTV needs to be installed in optimum locations following the specific crime analysis. The statistical analysis revealed that urban environmental factors such as street width, number of building floors, floor area ratio, recreational facilities, commercial facilities, and houses affect crime rates. Therefore, a safer city can be promoted by improving the urban physical environment.

UCPS can be used as a tool to overcome the limitation of the police and physical crime prevention facilities by providing crime information and user participation. In addition, UCPS helps police or local government for in developing crime prevention strategies such as the reinforcement of patrol in high crime areas and the improvement of the urban environment. However, USPC needs to be upgraded by strengthening functions such as crime prediction and information visualization. It is necessary to test the system through field applications.

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Web Sites
[1] British Police Website - http://www.police.uk/
[2] Crime Hunter - http://cafe.daum.net/tankcop/
[3] CrimeReports - https://www.crimereports.com/
[4] Cyber 112 - http://cyber112.police.go.kr/main/index.do
[5] Data SF - http://sanfrancisco.crimespotting.org/
[6] Fall in Love - http://polinlove.tistory.com/
[7] Safety Dream Youth School Violence - http://www.safe182.go.kr/schoolMain.do
[8] Wikicrimes - http://www.wikicrimes.org/